AMENDED CLAIMS

[Received by the International Bureau on 19 April 2005 (19.04.05): original claims 1, 3-6, 8, 10 and 11 amended; new claims 12-35; remaining claims unchanged (8 pages)]

Claims

1. A method for measuring a dimension on a substrate, the method comprising the steps of:

providing a nominal pattern comprising an array of features having a primary pitch of period *P* in a primary direction, wherein said nominal pattern is characterized by a nominal characteristic dimension that repeats at said period *P* along said primary direction, and said nominal characteristic dimension has a pre-determined variation along a direction substantially orthogonal to said primary direction;

forming a target pattern on the substrate corresponding to said nominal pattern, wherein said target pattern has a substrate characteristic dimension corresponding to said nominal characteristic dimension;

illuminating said target pattern with radiation characterized by at least one wavelength, so as to produce diffracted orders from said target pattern;

providing a relationship between a dimension of interest and a detected variation along said substantially orthogonal direction of one or more non-zeroth diffracted orders in response to a deviation of said substrate characteristic dimension relative to said nominal characteristic dimension;

detecting said variation of said one or more non-zeroth diffracted orders along said substantially orthogonal direction; and

determining said dimension of interest in accordance with said relationship, based on said detected variation of said one or more non-zeroth diffracted orders.

2. The method of claim 1, wherein said illumination comprises more than one wavelength, and said method further comprises detecting variations of said non-zero diffracted orders along said primary direction.

3. The method of claim 1, wherein said target dimension comprises a critical dimension.

4. The method of any of claims 1-3, wherein said detected variation comprises a variation in intensity of said one or more non-zeroth diffracted orders.

5. The method of any of claims 1, 2 or 12, wherein said nominal pattern comprises a first subpattern comprising subpattern features of a first tone characterized by a nominal length and width, and a second subpattern comprising features of a complementary tone having said nominal length and width, and wherein said method further comprises determining a deviation in process conditions from nominal based on deviations of corresponding target subpattern feature lengths and widths relative to said nominal length and widths.

6. The method of claim 1, wherein said target pattern comprises a first target portion formed on a first layer of the substrate, said first target portion corresponding to a first portion of said nominal target pattern, and a second target portion formed on a second layer of the substrate, said second target portion corresponding to a second portion of said nominal target pattern, and said dimension of interest comprises an offset of said first target portion relative to said second target portion in comparison to said nominal pattern.

7. The method of claim 6, wherein said detected variation comprises a variation in intensity and phase of said one or more non-zeroth diffracted orders.

8. An apparatus for performing the method of any of claims 1, 2, 3, 6, 7, 12, 13 or 14, comprising:

a source of radiation for illuminating said target pattern;

a detector for detecting said variation of one or more non-zero diffracted orders;

means for securing the substrate;

means for positioning said source, said substrate and said detector so that said source illuminates said target pattern, and so that said detector detects said variation of one or more non-zero orders of said radiation diffracted from said target pattern.

9. The apparatus of claim 8 further comprising:

a second detector for detecting the zeroth order of said radiation diffracted from said target pattern;

means for positioning said second detector relative to said source and said substrate so that said second detector detects said zeroth order; and

means for determining a second dimension of interest based on said detected zeroth order.

10. The apparatus of claim 8 wherein said apparatus is configured for in-line processing forsemiconductor manufacturing.

11. The apparatus of claim 9 further comprising:

means for determining a deviation in process conditions from nominal process conditions based on said variation of said one or more non-zeroth diffracted orders; and

means for providing adjustments in subsequent process conditions in response to said determined deviation in process conditions.

12. The method of claim 2 wherein said target dimension comprises a critical dimension.

13. The method of claim 2, wherein said target pattern comprises a first target portion formed on a first layer of the substrate, said first target portion corresponding to a first portion of said nominal target pattern, and a second target portion formed on a second layer of the substrate, said second target portion corresponding to a second portion of said nominal target pattern, and said dimension of interest comprises an offset of said first target portion relative to said second target portion in comparison to said nominal pattern.

14. The method of claim 13, wherein said detected variation comprises a variation in intensity and phase of said one or more non-zeroth diffracted orders.

15. The apparatus of claim 9, wherein said apparatus is configured for in-line processing forsemiconductor manufacturing.

16. The apparatus of claim 15 further comprising:

means for determining a deviation in process conditions from nominal process conditions based on said variation of said one or more non-zeroth diffracted orders; and

means for providing adjustments in subsequent process conditions in response to said determined deviation in process conditions.

17. A method for measuring a dimension on a substrate, the method comprising the steps of:

providing a target pattern on a substrate, said target pattern corresponding to a nominal pattern, said nominal pattern comprising an array of features characterized by a primary pitch of period P in a primary direction, said nominal pattern further characterized by a characteristic dimension defined along a direction substantially orthogonal to said primary

direction, wherein said target pattern has a substrate characteristic dimension corresponding to said characteristic dimension of said nominal pattern;

illuminating said target pattern with radiation characterized by at least one wavelength, so as to produce diffracted radiation from said target pattern;

providing a relationship for determining a dimension of interest along said primary direction in said target pattern as a function of a measurable quantity of one or more non-zeroth orders of said diffracted radiation along said substantially orthogonal direction to said primary direction, said measurable quantity of said one or more non-zeroth orders occurring in response to said substrate characteristic dimension in said target pattern;

detecting said measurable quantity of said one or more non-zeroth orders of said diffracted radiation; and

determining said dimension of interest in accordance with said relationship, based on said detected measurable quantity of said one or more non-zeroth orders of said diffracted radiation.

18. The method of claim 17 wherein said dimension of interest comprises a feature width of said features comprising said array of features in said target pattern.

19. The method of claim 18 wherein said characteristic dimension of said nominal pattern comprises a width of said features of said array that varies continuously along said substantially orthogonal direction.

20. The method of claim 19 wherein said characteristic dimension varies continuously according to a predetermined taper angle along said substantially orthogonal direction.

21. The method of claim 18 wherein said characteristic dimension of said nominal pattern comprises a width of said features of said array that varies discretely along said substantially orthogonal direction.

22. The method of claim 18 wherein said measurable quantity comprises the location of an extrema of intensity of said one or more non-zeroth orders along said substantially orthogonal direction.

23. The method of claim 18 wherein said nominal pattern comprises a first region having a first center position and a second region located adjacent to said first region, said second region having a second center position at a predetermined distance from said first center position along said substantially orthogonal direction, and said target pattern having corresponding first and second regions on the substrate, and wherein said measurable quantity comprises the distance between the location of an extrema in said one or more non-zeroth orders from said first region of said target pattern and the location of an extrema in said one or more non-zeroth orders from said second region of said target pattern.

24. The method of claim 17 wherein said measurable quantity comprise intensity of said one or more non-zeroth orders along said primary direction.

25. The method of claim 17 wherein said target pattern comprises a first region having features of a first tone, and a second region having features of a second tone different from said first tone, wherein the method further comprises comparing measurements obtained from said first region with measurements obtained from said second region to determine effects of process conditions.

26. The method of claim 25 wherein said process conditions are selected from the group consisting of dose, focus or a combination thereof.

27. The method of claim 17, wherein said nominal pattern comprises a first subarray of first features and a second subarray of second features, each subarray characterized by pitch P, wherein said first subarray and said second subarray are positioned so that said first features are positioned by a predetermined offset along said primary direction from said second features, and wherein said target pattern comprises a first target subarray corresponding to said first subarray having a first reflectivity and said target pattern further comprises a second target subarray corresponding to said second subarray having a second reflectivity, wherein said first and second target subarrays are characterized by an offset on the substrate corresponding to said predetermined offset, and wherein said dimension of interest comprises a difference between said offset on the substrate and said predetermined offset.

28. The method of claim 27 wherein said one or more non-zeroth orders comprises positive non-zero orders and the corresponding negative non-zero orders of said diffracted radiation.

29. The method of claim 28 wherein said measurable quantity comprises intensities of said one or more non-zeroth orders, and said relationship further comprises determining an effective amplitude and an effective phase difference between said first reflectivity of said first target subarray and said second reflectivity of said second target subarray.

30. The method of claim 27 wherein said predetermined offset varies continuously along said substantially orthogonal direction.

31. The method of claim 27 wherein said predetermined offset varies discretely along said substantially orthogonal direction.

32. An apparatus for performing the method of any of claims 17 - 31 comprising:

a source of radiation for illuminating said target pattern;

collection optics configured to collect said one or more non-zeroth orders along said primary direction and to image said target pattern along said substantially orthogonal direction; and

a detector array configured to detect spatial variations of said one or more non-zeroth orders from said collection optics along said substantially orthogonal direction and along said primary direction.

33. The apparatus of claim 32 further comprising a computer system comprising a computer readable storage medium, said computer readable storage medium comprising instructions for causing said computer system to determine said dimension of interest in accordance with said relationship, based on said detected measurable quantity of said one or more non-zeroth orders of said diffracted radiation.

34. The apparatus of claim 32 further configured to provide a second detector for detecting zeroth order radiation diffracted from said substrate, said apparatus further comprising means for determining film thickness from said zeroth order radiation.

35. The apparatus of claim 32 wherein said apparatus is configured for in-line processing for semiconductor manufacturing.